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Thesis

IMPROVED METHODS OF PREPARING INORGANIC COLLOIDS

by

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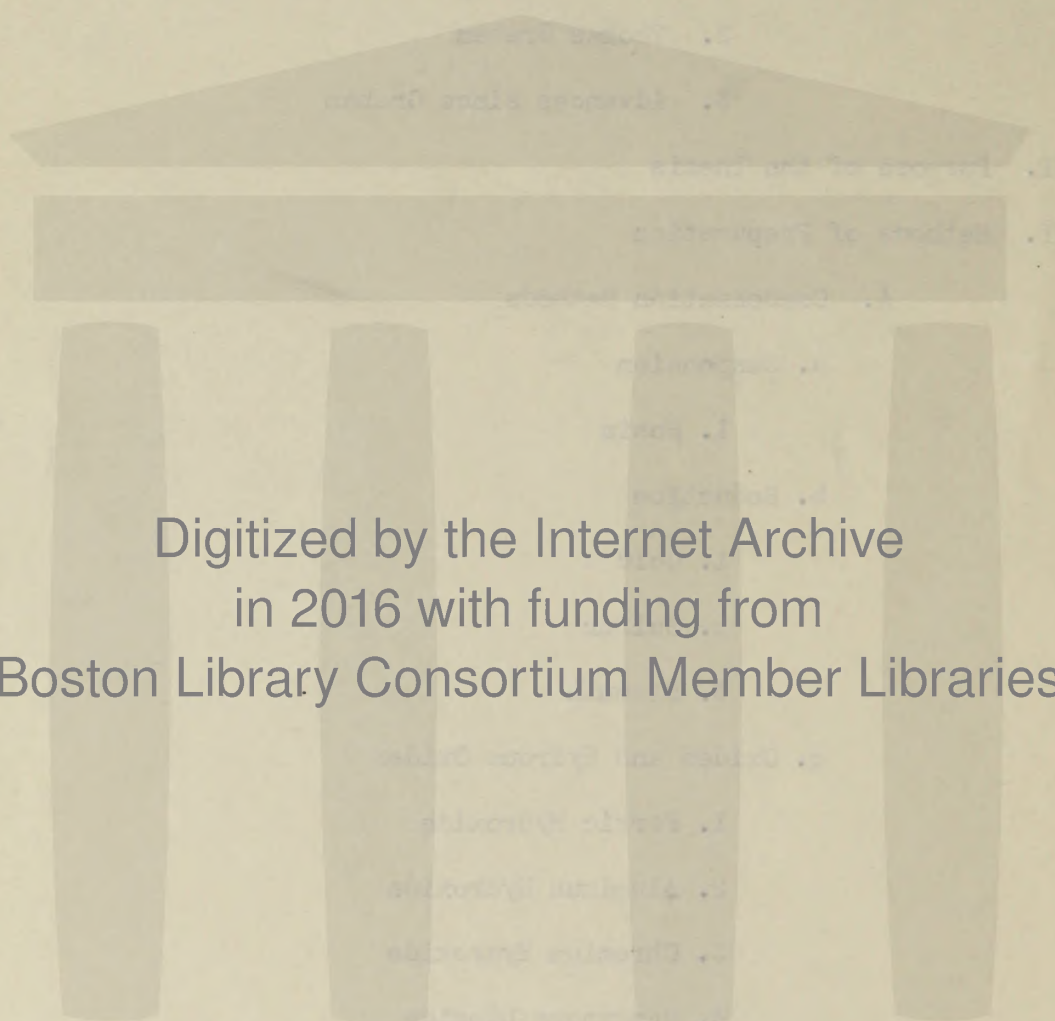
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IMPROVED METHODS OF PREPARING INORGANIC COLLOIDS

I. Historical Introduction

Such men as Richter 1802, Davy 1810, Berzelius 1838, Selmi 1847, and Faraday 1856 recognized the heterogeneous nature of colloidal solutions, namely that they were not molecular solutions, but very fine suspensions. Berzelius 1844 said that arsenious sulfide should be regarded as a suspension of transparent particles rather than as a solution because a precipitate of arsenious sulfide gradually separated out.¹

Faraday, 1856, discovered new methods for the preparation of gold sols by the reduction of gold chloride by phosphorus in ether. Although a great many observations had been made on gold sols, Faraday seems to have known nothing about them. He may be given credit for the discovery of protective action because he observed that if gelatin was added to his colloidal gold solutions, he could evaporate them to dryness without change in color.

Selmi, 1847, in his paper, "A Study of Pseudosolutions of Prussian Blue and of the Influence of Salts in Destroying Them", said that he believed there was a special type of association that came halfway between solutions and emulsions. The dispersed phase was so completely transparent that people believed it was dissolved,

¹ H.H.Holmes: Laboratory Manual of Colloid Chemistry P.12.

whereas it was merely dispersed through the medium in tiny flakes. Since he couldn't classify the mixtures, he coined a special name for them - pseudosolutions - so that they could not be mistaken for the true solutions which they resembled so closely.¹

However, it remained for Thomas Graham to lay the foundation of modern colloid chemistry. In his paper "Liquid Diffusion Applied to Analysis" read before the Royal Society, June 13, 1861, he outlined the differences in diffusibility of colloid and crystalloid. He found that while certain substances in solutions such as salt, sugar and alcohol passed through animal membrane quickly, other substances e.g., gelatin, starch, silicic acid, did not. Since the substances which did pass through the membrane quickly were such as generally crystallize well, whereas those that did not pass through were considered amorphous and non-crystallizable, Graham proposed to call them crystalloids and colloids. He believed that the distinction was one of "intimate molecular constitution". Now it is recognized that the distinction is one of degree of subdivision.

Graham also recognized the activity of colloids rising from their physical properties, e.g., their sensitivity to external agents and their changeability. He considered the colloidal state the dynamic one; the crystalloidal state, the static one.

1. Medical Life, March 1930.

In his second paper, Graham remarked that in crystalloidal solutions, the dissolved substance was in the molecular or ionic form, whereas colloidal solutions possessed particles of larger size formed by the grouping together of a number of smaller crystalloid molecules. He felt that the "basis of colloidal character was really this composite character of the molecule".¹ This is now known to be true.

Although Graham knew that the colloidal solutions were heterogeneous and contained particles of more than molecular size, the existence of such particles was made evident by the Tyndall Phenomenon. If a beam of light is passed through a colloidal solution, the path of the beam is traced by a diffused light. Faraday and later Tyndall made use of this phenomenon.

If instead of the unaided eye, a microscope is used, the range of vision is increased, and it is possible to detect particles which are much smaller than can be seen when the microscope is used in the ordinary way. On the basis of this principle, Siedentopf and Zsigmondy (1901) devised the ultra-microscope. A powerful beam of light is sent horizontally into the liquid under investigation at right angles to the line of vision through the microscope. The light will be reflected and dispersed by the particles which stand out as bright specks against a dark background in the field of view of the microscope.

¹ Alexander: Colloid Chemistry P.4.

Because of their smallness, these ultra-microscopic colloidal particles exhibit the phenomenon of Brownian movement. This is the continuous dancing movement first observed under the microscope by Robert Brown (1827), while he was working on pollen grains.

By the use of the ultramicroscope Zsigmondy was able to detect particles having a diameter as small as five millimicrons. From these investigations it was estimated that the colloidal state referred to matter in a state of subdivision lying between one tenth of a micron to one millimicron.

In 1908 Wilhelm Ostwald advanced the theory that colloids were dispersed systems lying between molecular solutions on one end and coarse suspensions on the other.

II. The Purpose of the Thesis

The purpose of this thesis is to verify and improve existing methods, to devise new methods of preparing certain inorganic colloids, and to endeavor to produce the desired result. In some cases success was immediate; in others, the directions of procedure were faulty, inadequate, or impossible of performance. In most cases I have indicated the changes in method, but it is an impossibility to include in this thesis, references to everything that was tried and everything that was improved. The work as it stands is a final record.

III. Preparations of Colloids

The colloidal state may be regarded as a general state of matter into which all substances under suitable conditions may be brought. This state may be produced by two methods - Dispersion Methods, and Condensation Methods. In the former, the mass is reduced to particles of colloidal size; in the latter, molecules unite to form particles of colloidal size.

A. Experimental Condensation Methods

a. Suspension

1. Colloidal Rosin. This is the simplest condensation method. 5 c.c. of a 1% solution of rosin in alcohol is poured into 250 c.c. of distilled water. A fine, white suspension forms which neither settles or filters out readily. In this method the solvent, alcohol, is replaced by a liquid, water, in which the solute, rosin, is insoluble and thus appears as a disperse phase.

b. Reduction

1. Colloidal Gold. The directions called for gold chloride, but the preparation may be modified by the use of gold leaf in aqua regia. Dissolved a sheet of gold leaf in 10 c.c. aqua regia. Boiled off the free chlorine and the oxides of nitrogen and evaporated almost to dryness. To 25 c.c. of distilled water added 1 drop of the gold chloride thus formed, then 1 drop of

the .1% tannic acid solution. Heated to boiling. A ruby red color appeared, which turned purple red to blue if more gold chloride was added as the directions stated. In order to retain the ruby red color, no further additions of either the gold chloride nor the tannic acid solution should be made. In this case a solution is formed by reducing the ions to metallic gold which is insoluble in the dispersion medium.

2. Colloidal Sulfur. This solution may be prepared in a variety of ways. 5 c.c. of an alcoholic solution of sulfur may be poured into 100 c.c. of water. It forms a bluish white suspensoid much like rosin.

According to De Bruyn a bright yellow colloidal sulfur sol is obtained by mixing 25 c.c. each of half normal sodium thiosulfate and hydrochloric acid. This method forms a very unstable sulfur solution.

The best results seemed to come from Oden's directions. A slow stream of hydrogen sulfide is introduced into a cold sulfur dioxide solution, until nearly all the odor of sulfur dioxide is gone. The sulfur is then precipitated as a coagulum by sodium chloride. After it is filtered and washed free of sodium chloride, the sulfur soon ran through the filter in colloidal form. The amount of colloidal sulfur increases as the concentration of sulfur dioxide decreases. Its stability depends on the formation of pentathionic acid ($\text{H}_2\text{S}_5\text{O}_6$).¹

¹ Holmes, Manual of Colloid Chemistry, P.33.

3. Colloidal Bismuth. Lottermoser claims that copper may be reduced just as bismuth is in the following directions. I did not find this to be so; however, the following method seems to be accurate and workable for bismuth.

Two and half grams of bismuth nitrate are dissolved in 2 c.c. of concentrated nitric acid in 10 c.c. of water and diluted to 12-1/2 c.c. Then this solution is treated with 10 c.c. of a 50% ammonium citrate solution and made strongly alkaline with 15 c.c. ammonia. Then 1.7 grams of commercial stannous chloride, dissolved in 5 c.c. of water, is mixed with 12-1/2 c.c. of the same ammonium citrate solution and neutralized with ammonia.

The tin salt solution is poured into the bismuth salt solution, diluted to 400 c.c., and heated on the water bath for at least three hours.

The solution, colorless at first, became dark brown and opaque, and a colored precipitate settled out slowly. Upon the addition of water the precipitate goes into colloidal solution. On long standing the colloid precipitates, but goes back into the colloidal form by addition of alkali; into the metallic form by addition of acid or salt.

c. Oxides and Hydrous Oxides

1. Ferric Hydroxide. To 100 c.c. of boiling distilled water, added enough ferric chloride, 30% solution, to give a decidedly red color. The salt is

1. Colloidal solutions. These are

colloidal solutions and are prepared from an emulsion in an

the following manner. 1. The first step is to

prepare the following reagents to be used in the

experiment for the purpose of

The first step is to prepare the

and dissolved in 100 c.c. of concentrated nitric acid in

10 c.c. of water and diluted to 100 c.c. Then this

solution is treated with 10 c.c. of a 5% aqueous solution

solution and the resulting solution is 10 c.c. of water.

Then 1.7 gram of anhydrous calcium chloride, dissolved

in 10 c.c. of water, is added with 10 c.c. of the

solution of the calcium chloride and the mixture

The first solution is added to

the mixture this solution, diluted to 100 c.c., and heated

on the water bath for 10 minutes.

The solution, after 10 minutes of heating, is

cool and brown and opaque, and a white precipitate

settles out slowly. On the addition of water the precipi-

rate goes into colloidal solution. On long standing the

colloid precipitates, but goes back into the colloidal form

by addition of alkali into the colloidal form by addition

of alkali on left.

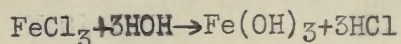
c. Calcium and Sodium Salts

1. Ferric Hydroxide. To 100 c.c. of

colloid ferric hydroxide, added enough ferric chloride, the

solution, to give a distinctly red color. The white

hydrolyzed with the formation of colloidal ferric hydroxide. The solution is precipitated in the presence of neutral salts and sulfuric acid, but is stable to boiling.



2. Aluminum Hydroxide₁. Hydrous aluminum oxide precipitated from 5 grams of $\text{Al Cl}_3 \cdot 6\text{H}_2\text{O}$, is washed by upward filtration until the filtrate no longer gives a test for a sulfate. The precipitate is then heated on a water bath in 100 c.c. of water and 1 c.c. of glacial acetic acid for at least three hours. A stable, milky-white solution is obtained which is easily precipitated by sulfuric acid and the neutral sulfates such as sodium sulfate.

3. Chromium Hydroxide₂. Made a 1% Chromium chloride solution. Diluted 50 c.c. to 200 c.c., heated to boiling. Added ammonium hydroxide to the boiling hot chromium chloride to precipitate chromic hydroxide. Boiled off the excess ammonia, let the precipitate settle. Washed by upward filtration. Removed the precipitate, dissolved half of it in 10 c.c. of hot concentrated hydrochloric acid, added the rest of the precipitate and allowed time for the chromium chloride to peptize the precipitate into a thick solution which is dissolved in water and diluted. Filtered and dialyzed in a collodion sack. A clear, green solution was obtained, stable to heating but coagulated by neutral salts.

¹ Vanino, P.469.

² Holmes, P.34.

precipitated with the addition of colloidal ferric hydroxide.
The solution is precipitated in the presence of neutral
salts and remains stable, but is stable to boiling.

1. *Aluminum Hydroxide* (100 g.)

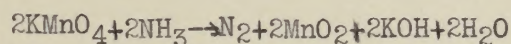
Aluminum oxide was heated for 2 hours at 1100°C. in
a stream of pure hydrogen. The residue was
dissolved in water for 24 hours. The solution is
then heated on a water bath at 100°C. for 24 hours and 1 g.
of phenol is added for at least three hours. A stable
slip-stable solution is obtained which is easily precipitated
by addition of acid and the neutral salts such as sodium
chloride.

2. *Aluminum Hydroxide* (100 g.)

Aluminum chloride was heated for 24 hours at 1000°C.
in a stream of pure hydrogen. The residue was
dissolved in water for 24 hours. The solution is
then heated on a water bath at 100°C. for 24 hours and 1 g.
of phenol is added for at least three hours. A stable
slip-stable solution is obtained which is easily precipitated
by addition of acid and the neutral salts such as sodium
chloride.

4. Manganese Dioxide₁. Although potassium permanganate does not react quickly with ammonium hydroxide at ordinary temperatures, a very dilute solution when heated to boiling and when concentrated ammonia is added drop by drop forms manganese dioxide in colloidal form.

Heated a .1% solution of potassium permanganate to boiling. While stirring added ammonium hydroxide at the rate of one drop every three minutes. At no time is there more than a faint odor of ammonia. The solution is kept at 90° C. It turned wine red, then coffee brown. To test if all the permanganate has been reduced, a little of the solution is coagulated with sodium chloride. Any violet color which may have been masked by the colloid is then visible. From the equation

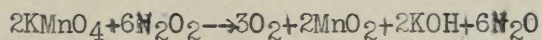


it will be seen that some potassium hydroxide is present. However, there is not enough to interfere with the solution and need not be neutralized. Although the directions suggest that the colloid be dialyzed, I have found that it cannot be dialyzed because of the coagulating effect of filter paper.

Colloidal manganese dioxide according to Marck₂ is made by the reduction of potassium permanganate with hydrogen peroxide. The permanganate must be at least 10 percent solution; the peroxide no more than 3 percent.

₁ Holmes, Laboratory Manual P.35.

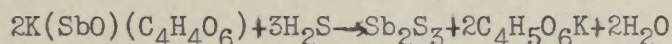
₂ Vanino, Handbuch der Preparativen Chemie P.672.



In a dilute condition this colloid is a bright yellow in color but becomes dark brown with increasing concentration. It is coagulated by electrolytes.

d. By Double Decomposition

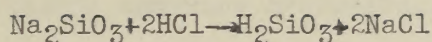
1. Antimony sulfide. Dissolved a small grain of tartar emetic, potassium antimonyl tartrate, in 100 c.c. of distilled water. Added hydrogen sulfide until the solution turned a deep orange color. At no time should the odor of hydrogen sulfide be markedly noticeable. This colloid is stable to boiling, but is coagulated by neutral salts, and sulfuric acid. This is the simplest preparation by double decomposition.



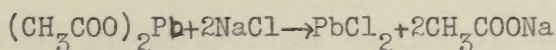
2. Silicic acid₁. Dissolved 30 grams of sodium silicate in 100 c.c. of water, and let the solution stand till cool.

Added with constant stirring a drop at a time 50 c.c. of a mixture of equal parts of concentrated hydrochloric acid and of water. Diluted to 150 c.c. The resulting solution is dialyzed until it gives only a faint turbidity with silver nitrate. If it is dialyzed too far, a gel will form. The solution is somewhat unstable and easily coagulated.

₁ Vanino, P.282.



3. Lead Chloride₁. To 7.6 grams of lead acetate dissolved in 15 c.c. of water, added 2.3 grams of sodium chloride dissolved in 5 c.c. of water. A very heavy, ropy precipitate of gelatinous colloidal lead chloride formed. This colloid cannot be dialyzed and is stable only about one day, then goes over into its crystalline form.



B. Dispersion Methods

a. Peptization

"True peptization is the transformation of a gel to a solution by addition of a small quantity of a dispersing agent."₂ The peptizer should be capable of chemical reaction with the colloid by increasing the true solution tendency of the colloid which enables the peptizer to form a soluble link between the molecules of colloid and liquid medium.₃

Svedberg says that the degree of dispersion is not altered by peptization but only the mutual distances between the particles. In other words, peptization by adsorbed ions is common whenever one ion of an electrolyte is more strongly adsorbed than the other for then the particles of a precipitate become positively or negatively charged and repel each other.

1. Cadmium Sulfide₄. To 2 c.c. of a 10% solution of cadmium sulfate diluted with water to 10 c.c.

₁ Vanino, P.590.

₂ Graham's definition of Peptization.

₃ Holmes, Laboratory Manual P.39.

₄ Vanino, Preparativen Chemie P.548.

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1. Item 100-100-100-100-100

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added 40 c.c. of dilute ammonium hydroxide, or just enough ammonium hydroxide to redissolve the precipitate first formed. Hydrogen sulfide is then introduced in a slow stream until the cadmium sulfide is completely precipitated. The precipitate is washed by upward filtration, and then is suspended in water and treated with a stream of hydrogen sulfide. During the addition, the sulfide, which was flocculent at first, becomes milky and goes over into the colloidal state. The excess hydrogen sulfide is boiled off. The solution is a clear, golden yellow by transmitted light, and is fluorescent by reflected light.

IV. Observed Properties of Colloidal Solutions

a. Diffusion and Dialysis

During the course of his investigations Graham found that colloids were sharply differentiated from crystalloids in respect to their ability to diffuse into a gelatine gel. Whereas crystalloids diffused quickly, colloids diffused very little or not at all.

Prepared a 5% gelatine gel. Added a layer of copper ammonium sulfate. Observed penetration throughout the whole gel within three hours.

To the same amount of gel added a layer of colloidal ferric ferrocyanide. No penetration occurred within the same length of time.

Another form of diffusion is known as dialysis. It gives a means of distinguishing between molecularly dispersed matter, existing in true solutions and

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matter in the colloidal state of subdivision. By this means the colloid may be obtained free from crystalloids or substances existing in molecular form. A collodion sack is prepared by covering the entire inner surface of a small Erlenmeyer flask with collodion, pouring off the excess collodion, and withdrawing the sack after a few minutes by filling the flask with water. The colloid is placed in the sack and immersed in water. The crystalloids diffuse readily, the colloids are retained. Taylor states that when colloidal ferric hydroxide is dialysed, at the end of nineteen days there remained only one part of hydrochloric acid for 30.3 parts of ferric hydroxide.¹

b. Optical Properties

1. Tyndall Effect. In a suspension, heterogeneity is at once apparent. As the size of the suspended particle decreases, it becomes more difficult to decide whether the solution is a two phase system. Faraday and later Tyndall observed that when a solution appeared to be quite clear, its appearance, when a concentrated beam of light was sent through it was similar to fluorescence.² It differs from fluorescence in that the light is polarized in its passage through the liquid. All colloids exhibit this phenomenon; true solutions do not.

2. Color. The color of colloidal solutions seems to depend to some extent on the dispersity of the particles, as well as the concentration of the

¹ W.W.Taylor, Chemistry of Colloids, P.214.

² W.W.Taylor, Chemistry of Colloids, P.38

disperse phase. In gold solutions the method of reduction and the amount of reducer added produced different colors, e.g., added one drop of .1% tannin to solution of gold chloride. A clear ruby red solution formed on heating the solution to boiling. To a second solution added a second drop of tannin when the solution was boiling. A purple-red solution was formed. To a third solution added two drops of tannin at the boiling point of the solution. A dull blue solution was obtained.

These changes are said to be due to a change in the size of the particles.

c. Precipitation

Since the stability of suspensoid colloids is mainly due to the electric charge carried by the particles and their consequent mutual repulsion, precipitation of the colloid is brought about by neutralizing the electric charge. This can be readily effected by the addition of an electrolyte. Hardy states that the precipitating power of an electrolyte depends on the valency of the ion whose electric charge is opposite to that on the solution.¹ The higher the valence the greater the precipitating power.

To 5 c.c. of colloidal ferric hydroxide added 1/2 gram of sodium chloride, precipitation occurred immediately. To separate portions of ferric hydroxide, added drop by drop solutions of sodium phosphate, sodium sulphate,

¹ Taylor, Chemistry of Colloids, P.102.

aluminum chloride, and barium chloride. (Precipitation was effected in the order enumerated above.) That is the phosphate ion was most effective because of its high valence, since colloidal ferric hydroxide carries a positive charge.

Taylor claims that the mechanism of precipitation is found in the fact, that when a solution is precipitated, the precipitate carries down with it the ion of opposite charge. Therefore, only the precipitating ion is adsorbed, and held so firmly that it cannot be washed out, but can be quantitatively replaced by other ions.

Mutual precipitation by colloids of opposite charge was effected by adding 5 c.c. of positive ferric hydroxide solution to 5 c.c. of negative antimony sulfide solution. In this case adsorption takes place with the formation of larger particles. When the proportions of the two colloids mutually adsorbed are such as produce an uncharged particle, complete precipitation takes place.

d. Colloidal Protection

The stability of the emulsoid colloid is mainly due to adsorbed dispersion medium - water and its charge. Such solutions are not so sensitive to added electrolytes. Although the addition of small amounts of an electrolyte may produce changes in the amount of water adsorbed by the colloid, actual precipitation does not take place until the concentration of added electrolyte is relatively large.

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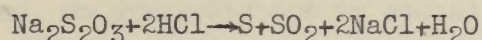
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When a suspensoid solution, e.g., colloidal metal, is mixed in suitable proportion with an emulsoid solution, e.g., gelatin or glycerin, the suspensoid loses most of its characteristic properties and gains those of the protecting emulsoid. Beckhold suggested that the protection is the result of adsorption. A thin layer of the emulsoid is adsorbed at the interface, and thus confers its stability on the adsorbing particle.¹

1. Colloidal Sulfur.² According to de Bruyn a bright yellow colloidal sulfur solution is obtained by mixing half normal equimolecular solutions of sodium thio-sulfate and hydrochloric acid. The solution quickly precipitates sulfur.



If gelatin is added, it can be made stable. Mixed 10 c.c. of a 20% gelatin solution with 5 c.c. of a .4 normal thio-sulfate solution and 10 c.c. of the gelatin solution with 5 c.c. of the hydrochloric acid. Poured the solutions together, at a temperature of 30°, and cooled quickly by pouring into a dish cooled in ice. In the gelatin, the clear colloidal solution remains for a short time, but begins to precipitate sulfur on standing.

2. Colloidal Zinc Sulfide.³ To 3 c.c. of a solution of .7 grams zinc sulfate in 100 c.c. of water, added 20 c.c. of glycerin and 10 c.c. of a mixture of 2.5 c.c. of polyammonium sulfide in 10 c.c. of glycerin.

¹ Taylor, Chemistry of Colloids, P.132.

² Vanino, Preparativen Chemie, P. 70.

³ Vanino, Preparativen Chemie, P. 536.

When a low-molecular solution, e.g., col-
loidal metal, is mixed in suitable proportion with an anti-
oxidant solution, e.g., solution of glycerol, the auto-oxidation
processes of the colloidal metal are retarded, and the rate
of the oxidation reaction is reduced. It is known that the
protection of the metal by the anti-oxidant is due to the fact that
the reaction is retarded at the interface, and the reaction
rate depends on the chemical composition.

1. Colloidal Metal, e.g., Iron

As known, a freshly prepared colloidal metal solution is ab-
solutely stable, but it becomes unstable when exposed to air.
The oxidation reaction of the colloidal metal is retarded by the
addition of an anti-oxidant solution, e.g., glycerol solution.

Method of Preparation of Colloidal Metal

If metal is added, it can be made stable. When a
small amount of metal is added to a solution of an anti-oxidant,
the oxidation reaction is retarded, and the rate of the oxidation
reaction is reduced. The reaction is retarded at the interface
between the metal and the anti-oxidant solution, and the reaction
rate depends on the chemical composition. The reaction is
retarded at the interface, and the reaction rate depends on the
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reaction rate depends on the chemical composition.

After shaking the whole mixture, decoloration occurred. The solution remained clear, when kept airtight. If exposed to the air, the solution is oxidized, becomes opalescent, and zinc sulfide precipitates in fine flakes.

3. Colloidal Nickel Sulfide.¹ According to Muller and Artman, to 40 c.c. of a .06% solution of nickel nitrate, added 5 c.c. of polyammonium sulfide. The solution is colored dark brown at first, without precipitating nickel sulfide. After twenty-four hours all the nickel sulfide is precipitated as a black precipitate. Glycerin was added as a stabilizer, so that after many weeks no visible particles of nickel sulfide had precipitated out.

When gelatin is added to a colloidal solution, no precipitation is caused by electrolytes unless the gelatin is first coagulated. Therefore, it is concluded that the more unstable solution assumes the properties of its protector.

e. Reactions in gels.

1. Banding. Made a 5% gelatin gel containing sodium sulfide. Allowed to harden and poured a layer of cadmium sulfate over it. Let stand. A bright yellow band of cadmium sulfide soon formed about a half inch from the top of the gel.

2. Liesegang rings. Made a 5% gelatin gel containing sodium sulfide. Allowed to harden. Removed from its container and placed in a large beaker

¹ Vanino, Preparativen Chemie, P. 628.

with sufficient cadmium sulfate to cover it. Let stand in a cool place for two days. Removed it from the beaker and cut it with a sharp knife. The cut surface shows concentric rings of cadmium sulfide.

These phenomena are due to the presence of a solid medium for in the presence of a gel, periodic precipitation takes place.

f. Adsorption

Since matter in the colloidal state is very finely divided, the extent of surface exposed is very large relatively to the total volume of the matter. Surface forces play a predominant part and bring about changes in the distribution and concentration at the surface of the particles. This surface phenomenon is known as adsorption. It is to this phenomenon that charcoal owes its property of removing coloring matter from solution.

Folded a small filter paper with a layer of norite, a specially prepared charcoal, placed upon it. Wet it thoroughly with water, let it drain. Slowly filtered through it a solution of congo red. The color was completely removed from it.

Repeated using ammonium hydroxide diluted twenty times. The odor of ammonia was very faint; the filtrate was practically neutral to red litmus.

Adsorption may be considered a concentration of the dispersed substance upon the solid adsorbing surface. Increase in concentration or positive

adsorption is most common. As can be seen by the above example, charcoal has this power to withdraw the dispersed particles from the medium in which it is the least soluble, e. g., water.

V. Conclusion

I have tried to give a representative preparation for each method of obtaining hydrosols, e.g., by suspension, colloidal rosin; by reduction, colloidal gold, sulfur, and bismuth; by hydrolysis, colloidal ferric hydroxide; by oxidation, colloidal manganese dioxide; by double decomposition, colloidal antimony sulfide, silicic acid, and lead chloride; and by peptization, colloidal cadmium sulfide.

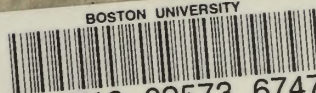
This paper is by no means a complete discussion of colloidal phenomena but rather a record of these verified and improved preparations.

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